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ELECTROACTIVE ELASTOMERIC STRUCTURE (EAES) FOR HYDROACOUSTIC APPLICATIONS R&D STATUS REPORT

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GENERAL ATOMICS PROJECT 3711
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GENERAL ATOMICS

R&D STATUS REPORT

SMART MATERIALS AND STRUCTURES

ELECTROACTIVE ELASTOMERIC STRUCTURE (EAES) FOR HYDROACOUSTIC APPLICATIONS

ARPA Order No.: BAA-94-17

Program Code No. Not Applicable

Contractor: General Atomics

Contract Amount: $739,177.00

Contract No.: N00014-94-C-0264

Effective Date of Contract: 29 September 1994

Expiration Date of Contract: 30 November 1996

Principal Investigator: Dr. Terry D. Gulden

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Short Title of Work: Electroactive Elastomeric Structure (EAES)

Reporting Period: 29 September 1994 through 31 December 1994

DESCRIPTION OF PROGRESS

The emphasis in the first quarter of the program has been on materials modeling, formulation of state-of-the-art electroactive materials, verification of materials integrity in the Naval Undersea Warfare Center (NUWC) Quiet Water Tunnel with a series of stability tests, and preparation for the first performance test series. Work is proceeding well in all areas with no major problems. A particular highlight was the successful completion of a series of stability tests in the NUWC Quiet Water Tunnel that verified the integrity of the material, the fixturing arrangement, and the concept of a metallized scrim cloth electrode under representative operating conditions.

Materials Modeling

The initial modeling iteration based on a simple electrical-mechanical analogy has been completed. The simplest approach based on a Voight model was unsuccessful in describing the viscoelastic behavior of electrorheological material over a range of frequencies. Subsequently a three element model, consisting of a spring and a Voight element in series was adopted. The composite EAES material was modeled by a linear superposition of the elastic properties of the matrix and the imbedded electrorheological material. The model gives good qualitative agreement with storage modulus and loss modulus data measured from 0 to 350 Hz on previous programs. Trends are represented quite well and limiting values are reasonably well represented. Comparisons to date suggest that the ER fluid contribution due to the application of the electric field dominates the viscous behavior of the composite EAES material. Indications are that considerable improvement can be made in materials response without exceeding the applied electric fields currently being used.

Materials Formulation and Qualification Testing

Several specially formulated electrorheological fluids have been received from ERFD, Ltd. Initial fabrication trials have shown that the fluids are compatible with the EAES concept.

Candidate electrorheological elastomeric materials have been selected for the initial performance test series at NUWC. The baseline material will contain 87% by weight of ER fluid, with 6.5% silicone resin and 6.5% catalyst. The ER fluid composition will be 33 wt % particles in a silicone oil. The viscosity of the polydimethylsiloxane oil will be 20 centistokes.

The EAES materials for the performance tests will be selected based on dynamic shear performance. Values of G' and G'' will be determined from linear displacement data, load cell data, and the phase angle between the displacement and the load, using methods developed and refined in previous programs. The test apparatus and instrumentation are in place; and testing is scheduled to begin in the near future.

The concept of a metallized scrim cloth electrode embedded in the surface of the EAES material has been developed. This has significant potential advantages in terms of ease of fabrication, uniformity of electric field, and ability to conform with the structure. It also provides added toughness and abrasion resistance to the near-surface of the EAES material. We have successfully fabricated this material design concept and tested it in the stability tests described below.

Quiet Water Tunnel Stability Tests

To resolve concern that the flow conditions in the Quiet Water Tunnel could damage or degrade the EAES material, especially at the lines of attachment to the fixture, it was decided to run a series of nonelectrical stability tests in the tunnel under representative operating conditions. Three samples, approximately 4.5 in. square and 0.18 in. thick, were prepared using two different attachment schemes, and the scrim electrode concept. The samples were installed in a stainless steel port plug on the top wall of the test section in well 4. The centerline fluid velocities were varied from 5 to 20 ft/sec, with a static pressure varying from 15 to 45 psi. The momentum thickness Reynolds Number varied from approximately 5,000 to 20,000. All three samples showed excellent integrity, with no apparent degradation in the tests. The stability test results confirmed that the fabrication procedures are effective and the coatings are suitable for testing in hydrodynamic boundary layers at moderate to high Reynolds Numbers. A video of the test has been supplied to the ONR Program Officer.

Performance Testing

Design concepts for the test articles for both the quiet water tunnel and the acoustic tube have been developed. Test facility modification concepts and experimental interfaces have also been developed to support the test article designs. Acrylic tubing for the water tunnel tests has been specified and purchased. A five section test configuration, consisting of a 40 pipe diameter length initial section to ensure fully developed pipe flow, three test sections and a final run-out section, has been designed and will be fabricated at GA. The center test section will contain an EAES sample spanning 90 degrees of arc within the circular tube. The EAES material and associated electrode structure will be molded in place in a 4.5 mm deep depression milled into the acrylic tube. The length of the EAES sample is limited by the available power supply to about 7 in. The sample configuration for the Quiet Water Tunnel Tests is illustrated in Fig. 1.

Most of the required instrumentation is either on hand or has been ordered. Hot film velocity sensors and mounting fixtures are on order. Wall pressure sensors have been fabricated and are currently being calibrated. Hardware and software modifications for data acquisition are being developed.

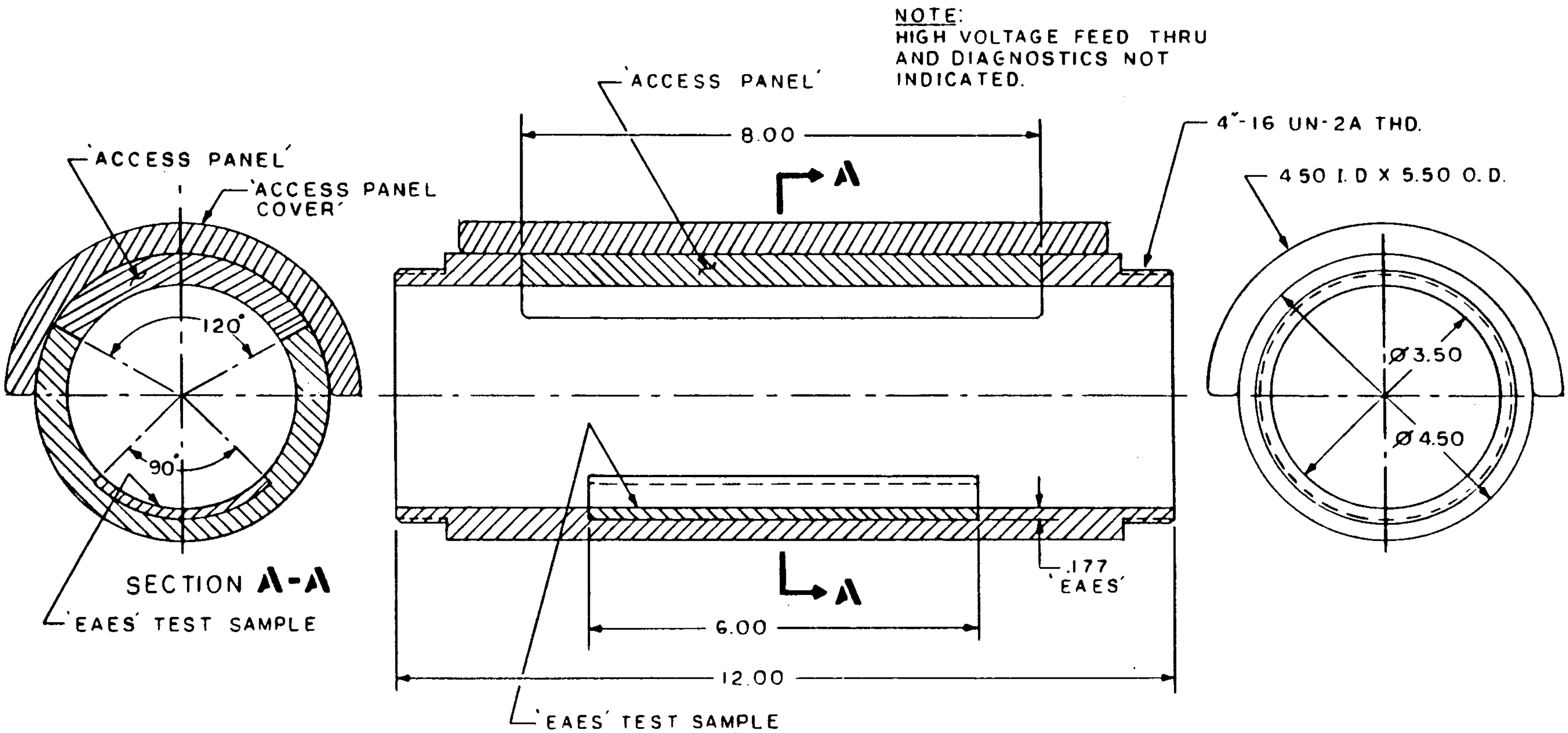


Fig. 1. Sample configuration for Quiet Water Tunnel performance tests

The preliminary design of the acoustic chamber endplate and test article fixture for the acoustic tube has been completed, and is illustrated in Fig. 2. The EAES material and electrodes will be cast onto a flat plate in the endplate section. The EAES thickness can be readily varied.

Schedule Status

A Gannt Chart for the program is attached as Fig. 3. The program is on schedule and no particular problems are currently foreseen.

CHANGE IN KEY PERSONNEL

Mr. Fred Elsner has taken another position within General Atomics and is no longer available to work on this program. He has been replaced with Mr. Joel Drake. Mr. Drake has a B.S. Degree in Physics and 5 years of diversified experience in experimental physics at General Atomics. He is fully qualified to perform the required work.All other key personnel remain as described in the contract.

SUMMARY OF SUBSTANTIVE INFORMATION DERIVED FROM SPECIAL EVENTS

A program kickoff meeting was held at NUWC New London Detachment, attended by personnel from General Atomics, NUWC, ONR, and NRL. The program plan and schedule were reviewed in detail; and the NUWC test facilities were examined. Interface sketches were developed; and concepts were established for test article design and fabrication. Preliminary dimensions of the EAES test sections for each of the test facilities were established and instrumentation requirements as they relate to the fabrication of the test articles were reviewed. It was decided that the stability tests as described above should be performed to verify the integrity of the EAES material and the fixturing in the Quiet Water Tunnel.

PROBLEMS ENCOUNTERED AND/OR ANTICIPATED

At this point we anticipate no difficulties in meeting the program objectives.

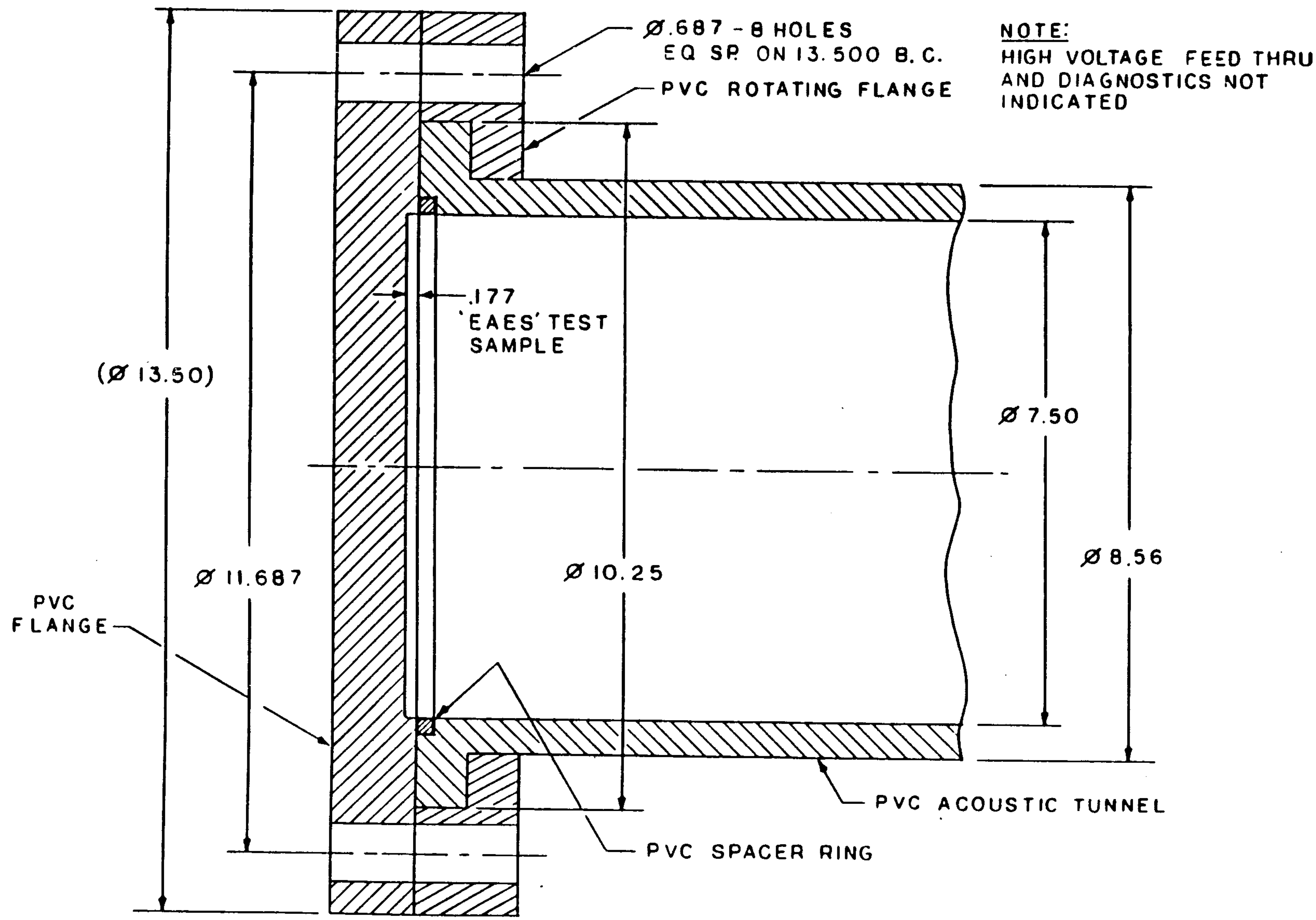
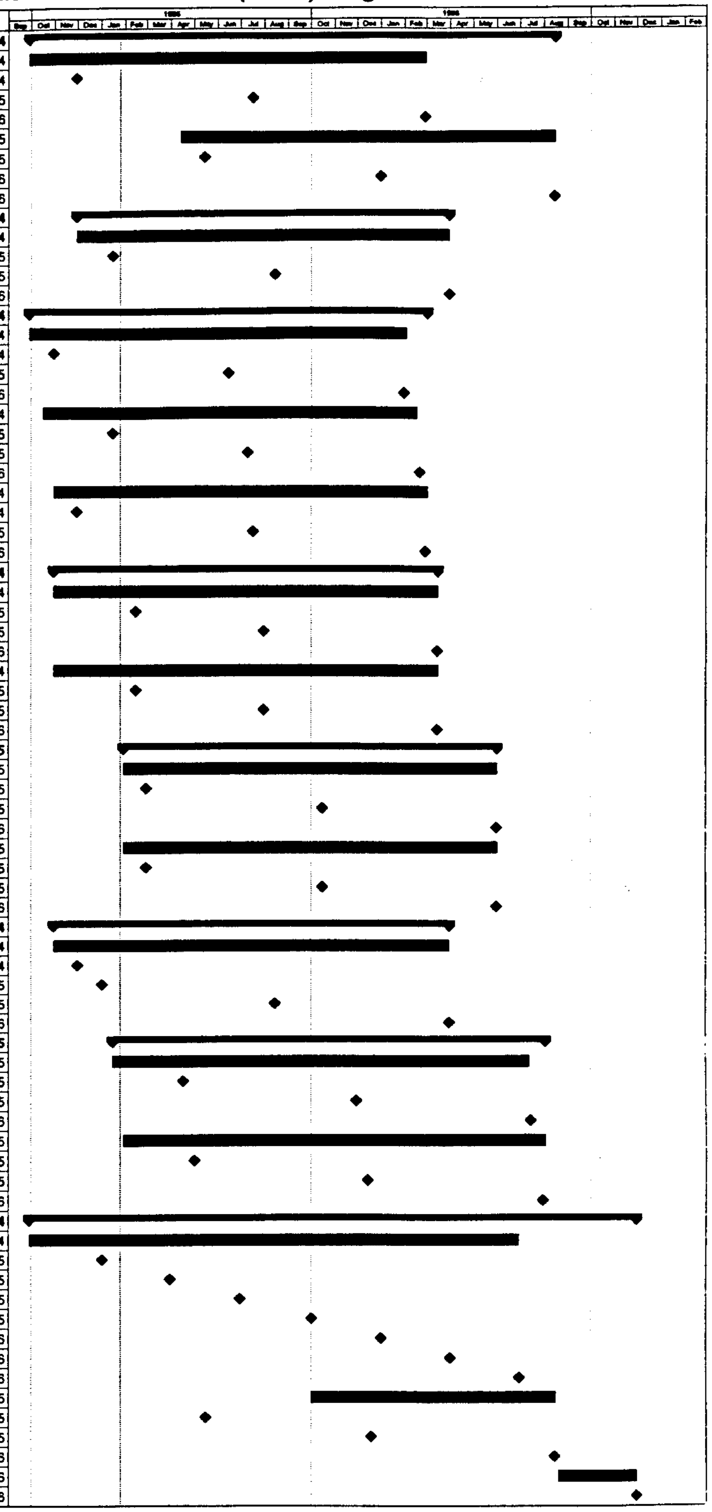


Fig. 2. Sample configuration for the acoustic tube performance tests

Figure 3: Electroactive Elastomeric Structures (EAES) Program

ID	Task Name	Duration	Start
1	**1.0 Hydrodynamic/Acoustic Modeling**	**491d**	**9/29/94**
2	1.1 Performance Modeling	370d	9/29/94
3	*1-1 Complete Initial Performance Model*	0d	11/30/94
4	*1-2 Complete Second Performance Model Iteration*	0d	7/17/95
5	*1-3 Complete Final Performance Model*	0d	2/28/96
6	1.2 Model Evaluation	350d	4/14/95
7	*1-4 Verification of Initial Model*	0d	5/15/95
8	*1-5 Verification of Second Model Iteration*	0d	1/1/96
9	*1-6 Verification of Final Model*	0d	8/15/96
10	**2.0 Test Definition and Planning**	**348d**	**11/30/94**
11	2.1 Develop Test Specifications	348d	11/30/94
12	*2-1 Specification for initial test series*	0d	1/16/95
13	*2-2 Specification for second test series*	0d	8/15/95
14	*2-3 Specification for final test series*	0d	3/31/96
15	**3.0 EAES Material Structures Development**	**372d**	**9/29/94**
16	3.1 Composition Variation/Optimize	352d	9/29/94
17	*3-1 Specify material for initial test series*	0d	10/31/94
18	*3-2 Specify material for second test series*	0d	6/15/95
19	*3-3 Specify material for final test series*	0d	1/31/96
20	3.2 Qualification Testing	350d	10/17/94
21	*3-4 Complete initial qualification test series*	0d	1/16/95
22	*3-5 Complete second qualification test series*	0d	7/10/95
23	*3-6 Complete final qualification test series*	0d	2/21/96
24	3.3 Conducting Elastomer Variation	350d	10/31/94
25	*3-7 Specify conducting elastomer for first test series*	0d	11/30/94
26	*3-8 Specify conducting elastomer for second test series*	0d	7/17/95
27	*3-9 Specify conducting elastomer for final test series*	0d	2/28/96
28	**4.0 Active Control Specification and Development**	**360d**	**10/31/94**
29	4.1 Control Software Development	360d	10/31/94
30	*4-1 Complete control software for initial test series*	0d	2/15/95
31	*4-2 Complete control software for second test series*	0d	7/31/95
32	*4-3 Complete control software for final test series*	0d	3/15/96
33	4.2 Hardware and Sensor Integration	360d	10/31/94
34	*4-4 Complete control software and sensor specification*	0d	2/15/95
35	*4-5 Complete control software and sensor specification*	0d	7/31/95
36	*4-6 Complete control software and sensor specification*	0d	3/15/96
37	**5.0 Test Article Design and Fabrication**	**350d**	**1/30/95**
38	5.1 Hydroacoustic Panels	350d	1/30/95
39	*5-1 Complete fabrication of hydroacoustic panels*	0d	2/28/95
40	*5-2 Complete fabrication of hydroacoustic panels*	0d	10/16/95
41	*5-3 Complete fabrication of hydroacoustic panels*	0d	5/31/96
42	5.2 Anechoic Discs	350d	1/30/95
43	*5-4 Complete fabrication of anechoic discs*	0d	2/28/95
44	*5-5 Complete fabrication of anechoic discs*	0d	10/16/95
45	*5-6 Complete fabrication of anechoic discs*	0d	5/31/96
46	**6.0 Forming and Fabrication Procedures Development**	**370d**	**10/31/94**
47	6.1 Develop Molding and Bonding Techniques	370d	10/31/94
48	*6-1 Deliver stability test samples to NUWC*	0d	12/1/94
49	*6-2 Complete development of molding and bonding techniques*	0d	1/2/95
50	*6-3 Complete development of molding and bonding techniques*	0d	8/15/95
51	*6-4 Complete development of molding and bonding techniques*	0d	3/31/96
52	**7.0 Performance Testing**	**405d**	**1/16/95**
53	7.1 Setup and Operations	390d	1/16/95
54	*7-1 Complete initial performance test series*	0d	4/17/95
55	*7-2 Complete second performance test series*	0d	11/30/95
56	*7-3 Complete final performance test series*	0d	7/15/96
57	7.2 Data Reduction and Analysis	395d	1/30/95
58	*7-4 Complete data analysis for initial test series*	0d	5/1/95
59	*7-5 Complete data analysis for second test series*	0d	12/15/95
60	*7-6 Complete data analysis for final test series*	0d	7/31/96
61	**8.0 Management and Reporting**	**567d**	**9/29/94**
62	8.1 Quarterly Reports	457d	9/29/94
63	*8-1 Submit quarterly report*	0d	1/2/95
64	*8-2 Submit quarterly report*	0d	3/31/95
65	*8-3 Submit quarterly report*	0d	6/30/95
66	*8-4 Submit quarterly report*	0d	10/2/95
67	*8-5 Submit quarterly report*	0d	1/1/96
68	*8-6 Submit quarterly report*	0d	4/1/96
69	*8-7 Submit quarterly report*	0d	6/30/96
70	8.2 Program Reviews	229d	10/2/95
71	*8-8 Program review meeting*	0d	5/16/95
72	*8-9 Program review meeting*	0d	12/19/95
73	*8-10 Program review meeting*	0d	8/15/96
74	8.3 Final Report	74d	8/20/96
75	8.11 Complete Final Report	0d	11/29/96



1/25/95

Fig. 3. Project 3711: Electroactive Elastomeric Structures (EAES) Program

ACTION REQUIRED BY THE GOVERNMENT

No action required.

FISCAL STATUS

1. Amount currently provided on contract: $600,000 (incremental funding)
2. Expenditures and commitments to date: $124,415 (as of 31 December 1994)
3. Funds required to complete work: $614,762